Households stoves: energy, health, and global warming

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EWC Simulated Village House:
Size Distribution of Biomass Smoke Particles

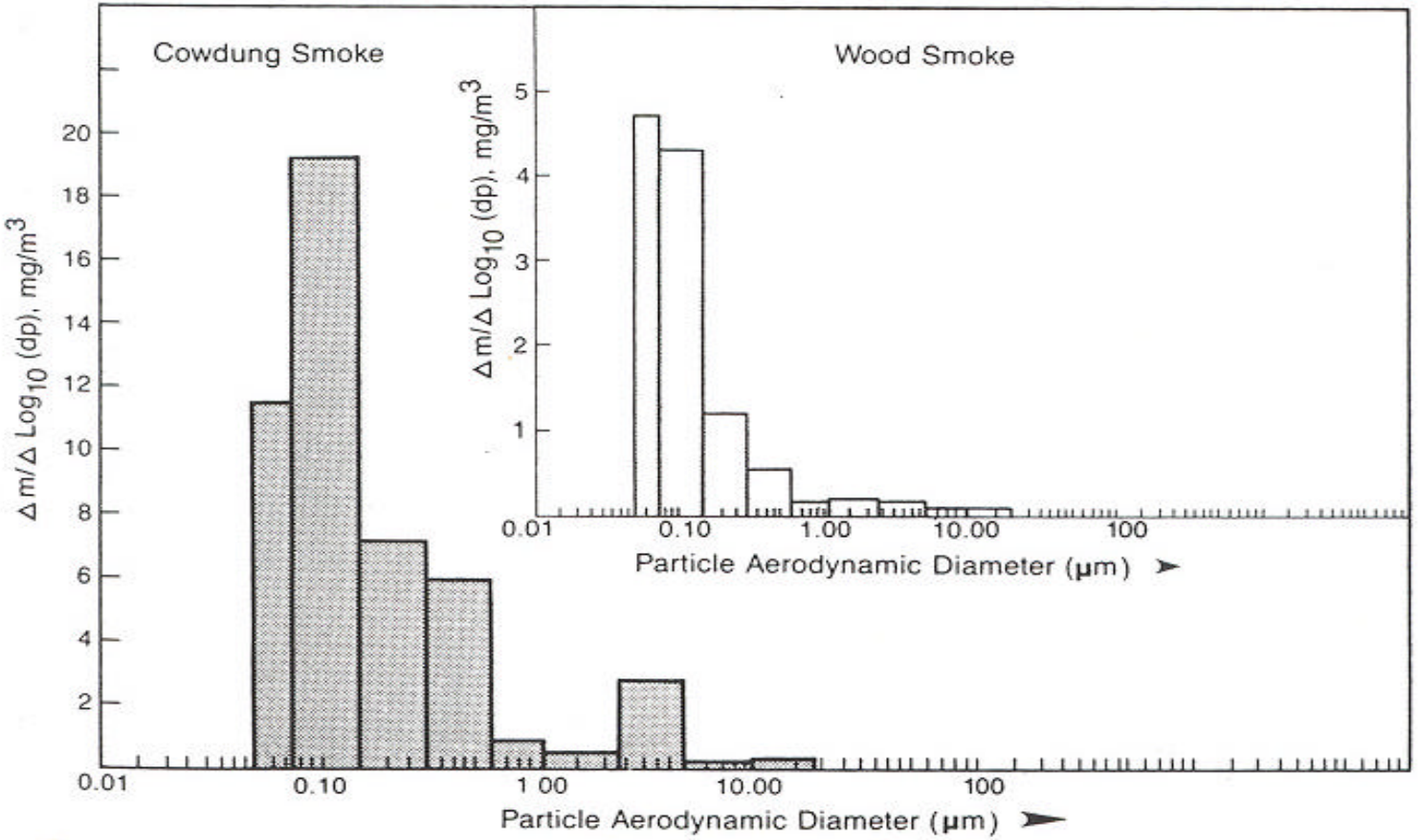
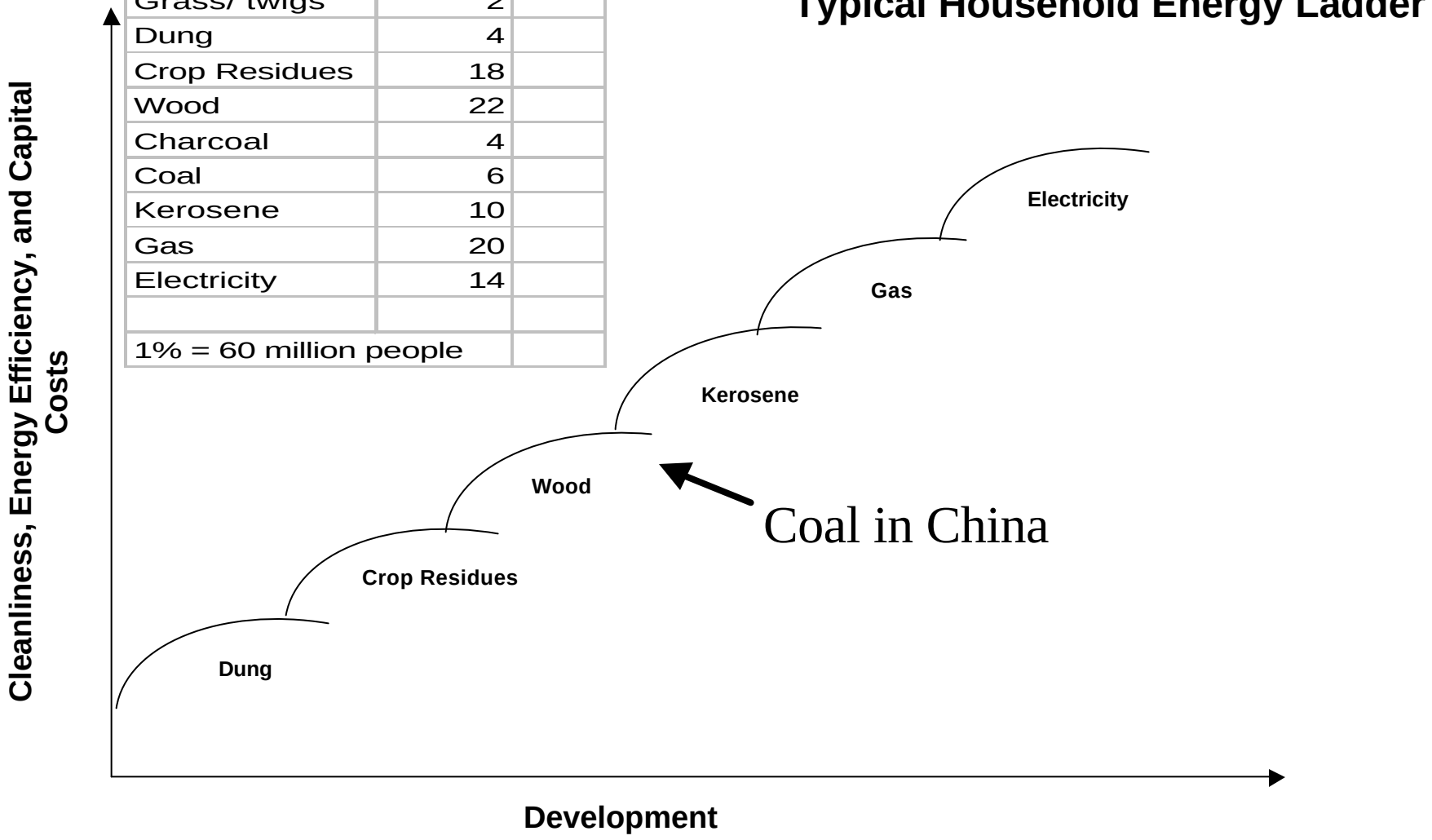


Figure 2.2. Size distribution of woodsmoke and dungsmoke particles. Measurements taken in the East–West Center simulated village house as reported in Smith *et al.* (1984b). (Figure prepared by Premlata Menon.)

Global Energy Ladder		
(Approximate % of Population)		
Grass/ twigs	2	
Dung	4	
Crop Residues	18	
Wood	22	
Charcoal	4	
Coal	6	
Kerosene	10	
Gas	20	
Electricity	14	
1% = 60 million people		

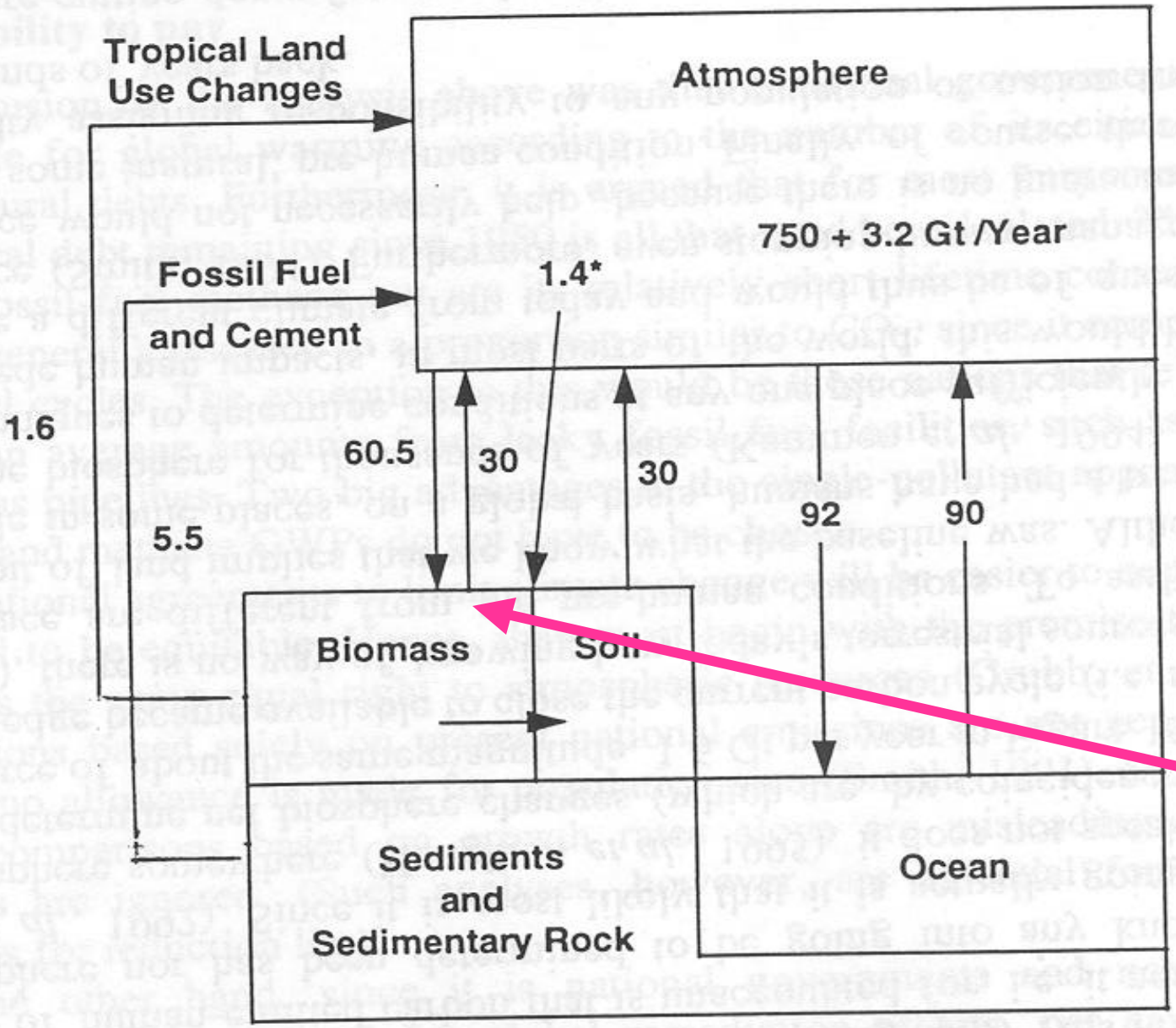


Two Important Policy Questions about a Possible Intervention

- Does it address a significant proportion of global warming and/or other negative impacts?

- Is it a cost-effective way to address these negative impacts?

Global Carbon Cycle



Triple Carbon-Balance Analysis of a combustion device

- Energy
- Health
- Global Warming

Carbon-balance Analysis: Combustion

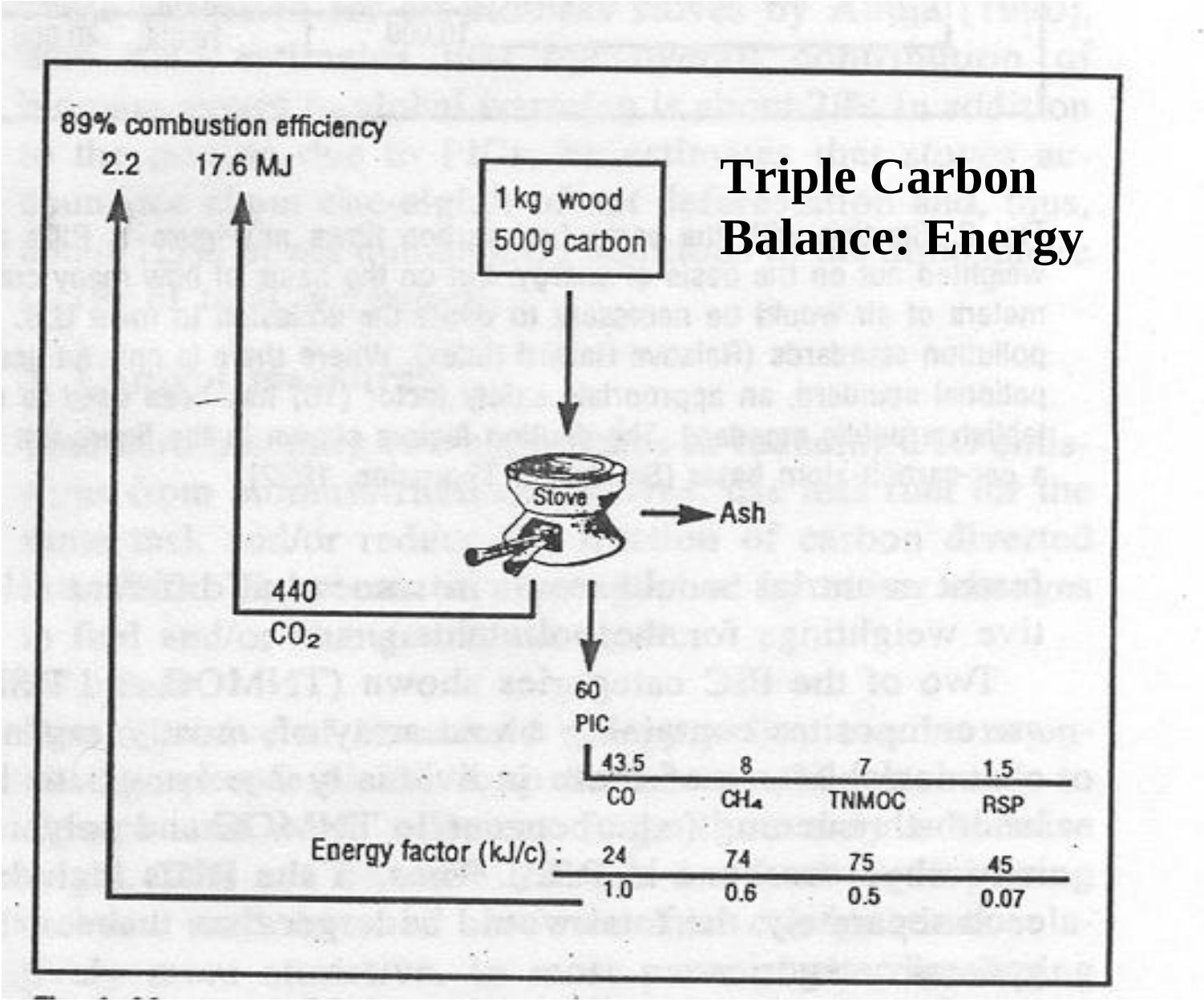
- Follow the fuel carbon

$$C_f = C_{CO_2} + PIC$$

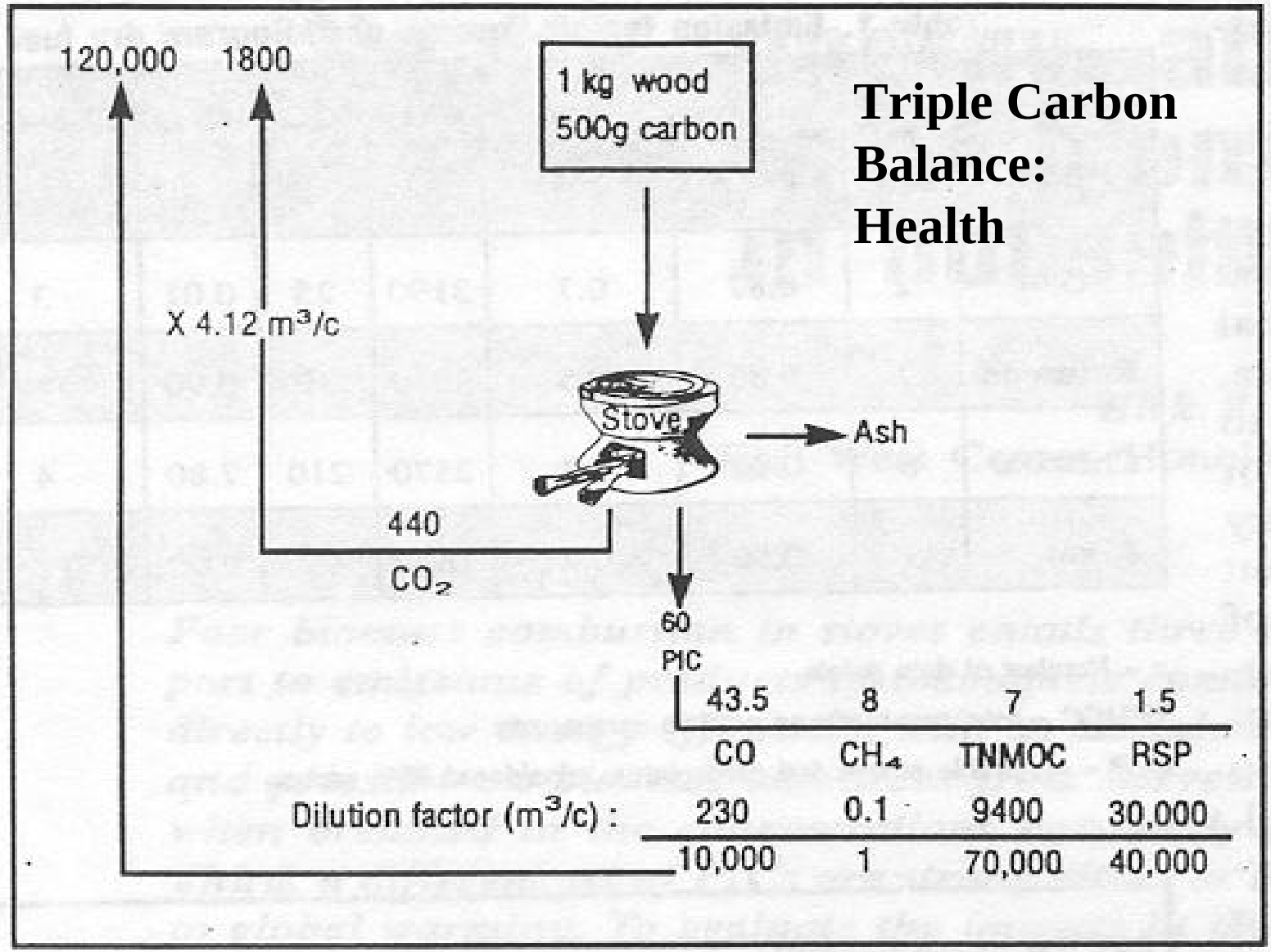
- PIC =

$$C_{CH_4} + C_{CO} + C_{TNMHC} + C_{TSP}$$

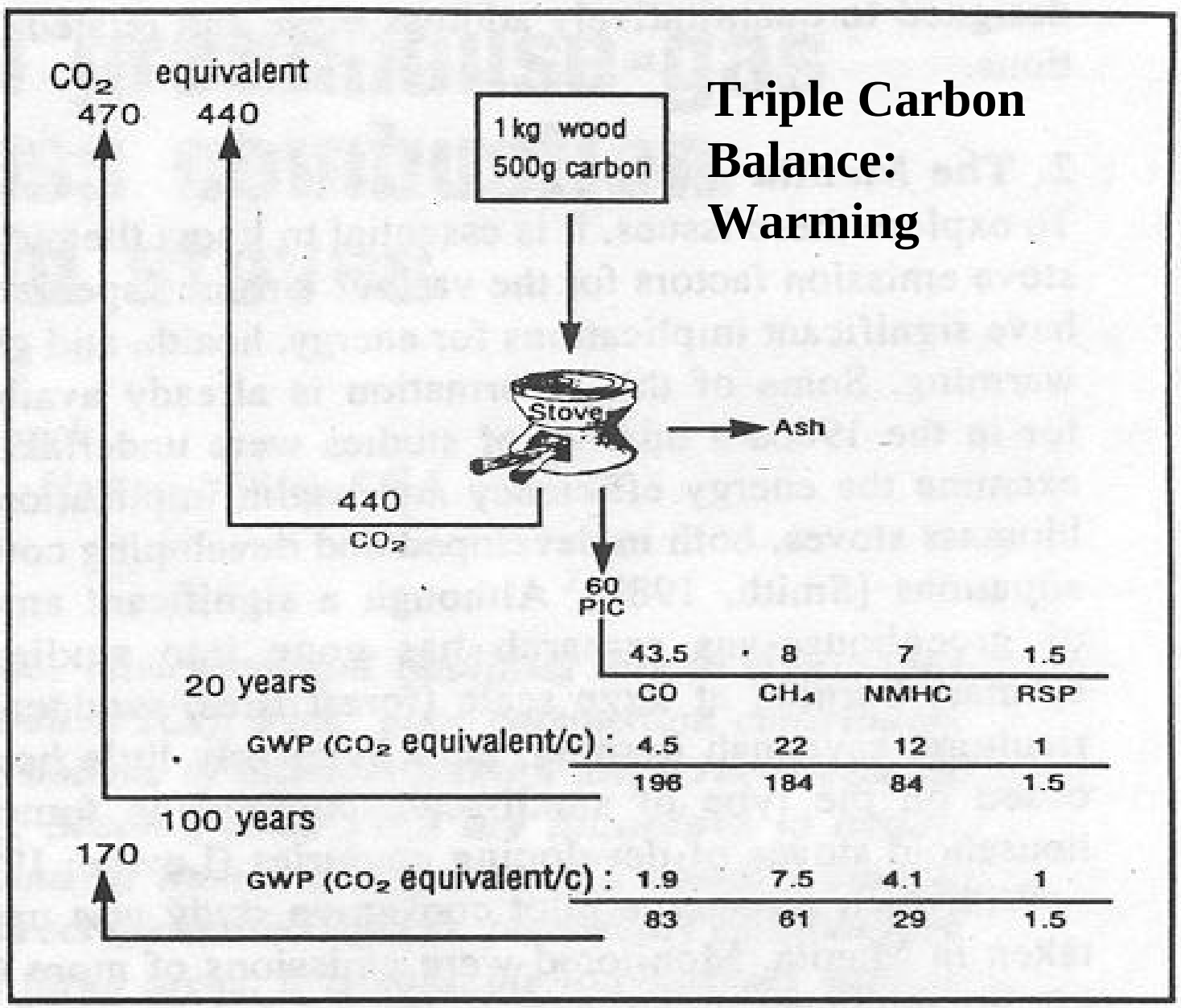
Triple Carbon Balance: Energy



Triple Carbon Balance: Health



Triple Carbon Balance: Warming



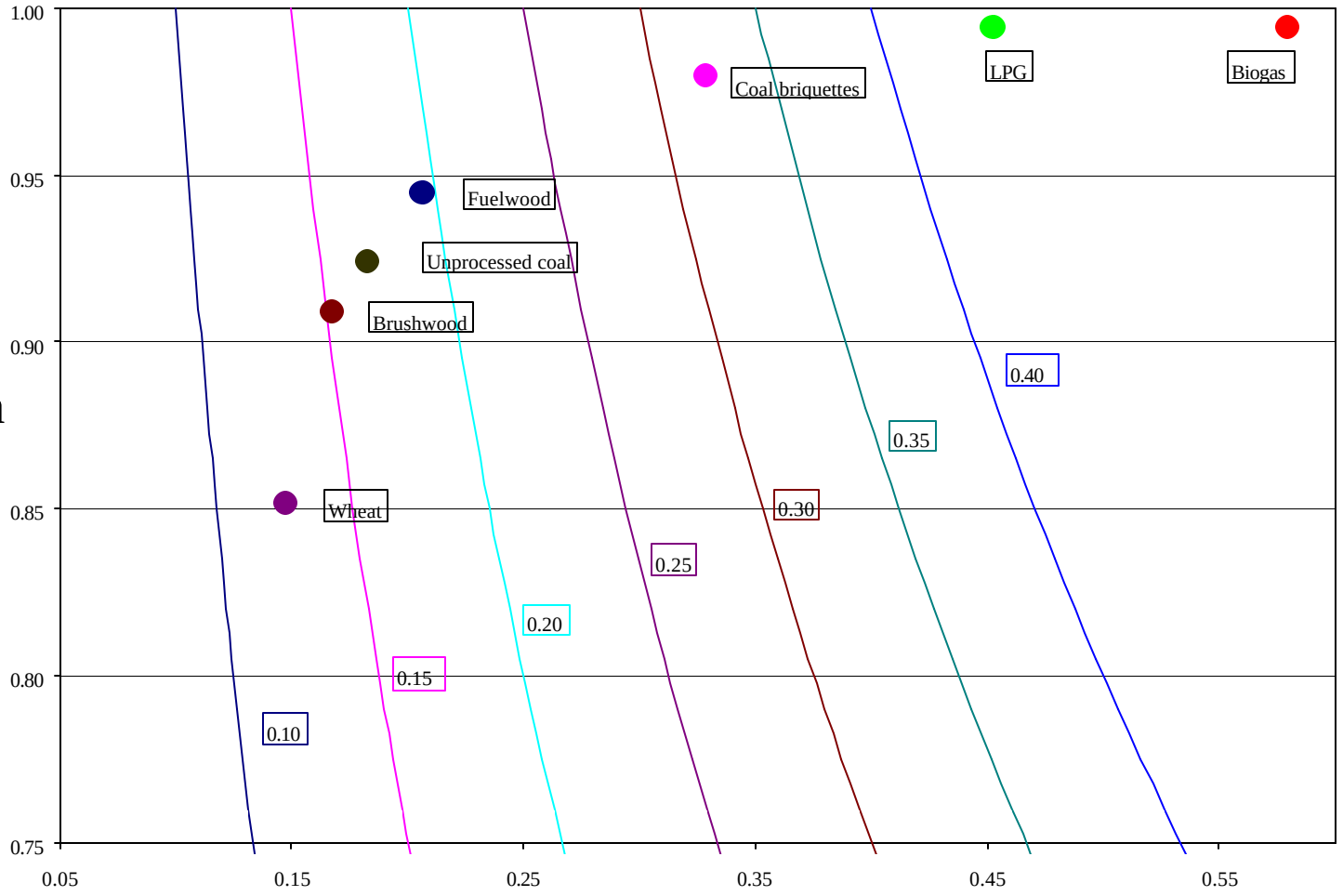
Carbon-balance: Efficiencies

- Establish carbon balance while measuring overall efficiency (OE)
- OE is function of two internal efficiencies
  OE = NCE * HTE
- Nominal Combustion Efficiency (NCE) = percent of fuel carbon released as CO_2
- Heat transfer efficiency (HTE) = OE/NCE
- NCE = $CO_2/(CO_2 + PIC)$ -- on a carbon basis

Nominal Combustion Efficiencies in Indian Stoves

- Gas: ` 99% (98-99.5)
- Kerosene: 97 (95-98)
- Wood: 89 (81-92)
- Crop residues: 85 (78-91)
- Dung: 84 (81-89)

Chinese Stove efficiencies HTE VS NCE



Nominal Combustion Efficiency

Heat Transfer Efficiency

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Calculation of global warming commitments

- 20-year GWP Smith et al 2000

  Molar basis (per carbon atom)

  CO_2 1.0

  CH_4 22.6

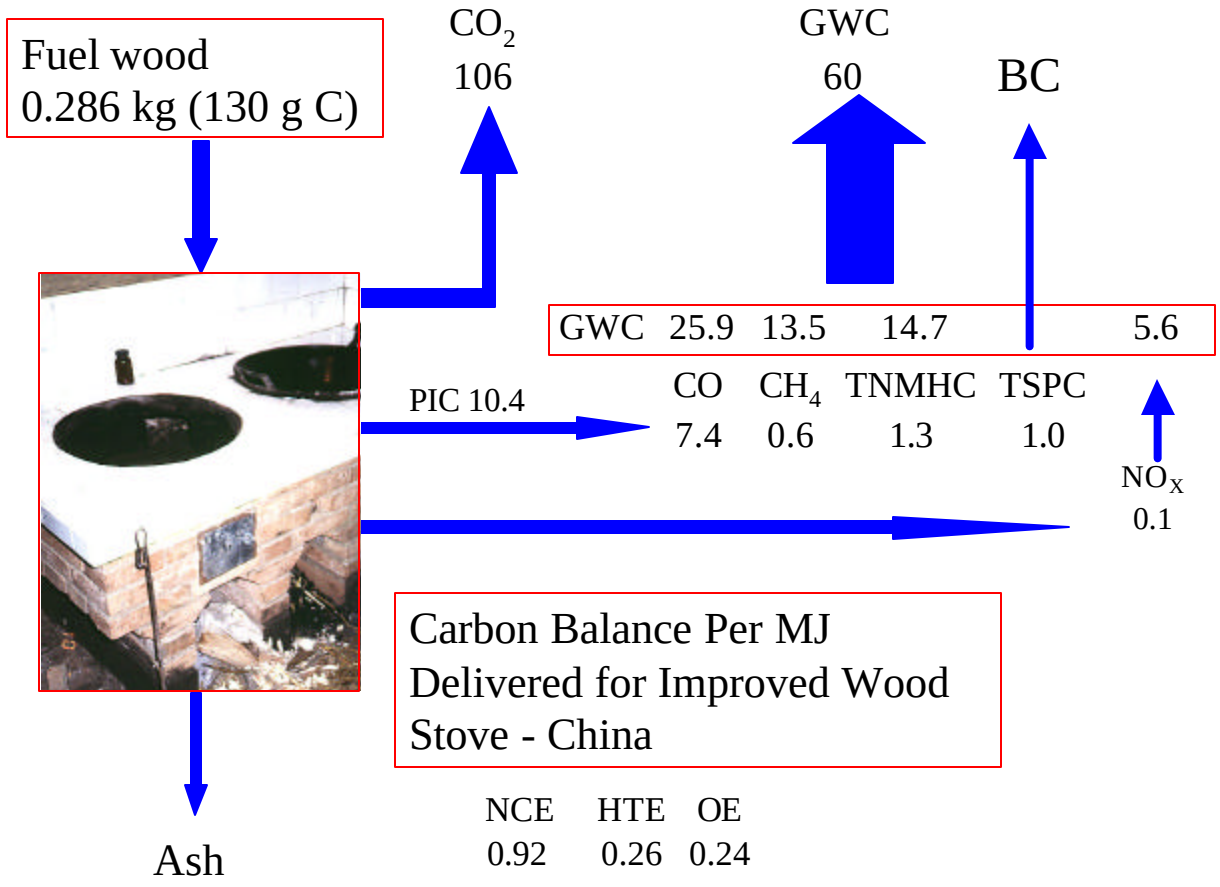
  CO 4.5

  TNMHC 12
- 20-year GWP IPCC 1990

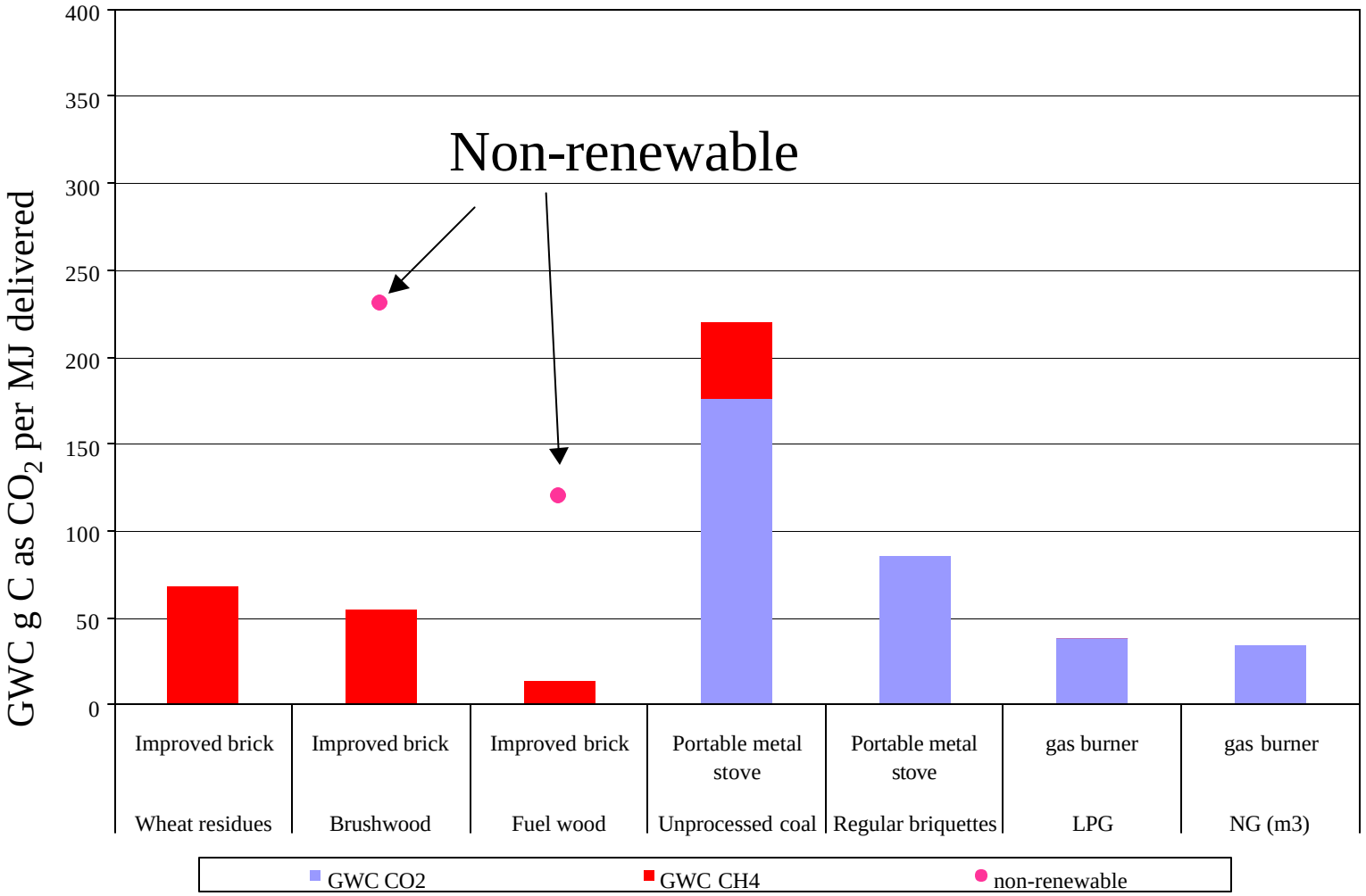
  per kg relative to CO_2

  NO_x 150
- Black carbon?

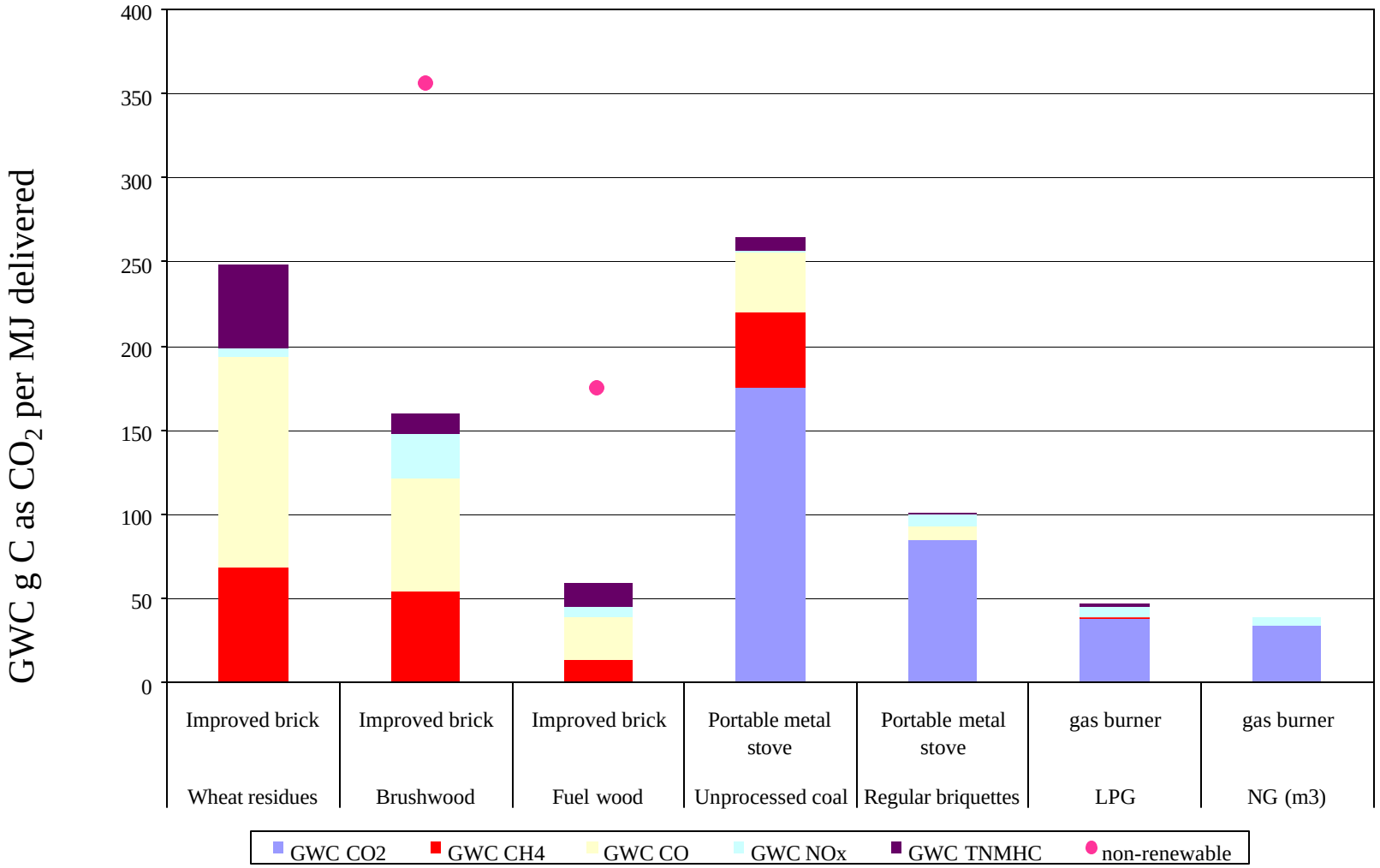
Tracing fuel carbon: Chinese improved wood



GWC of different household fuels in China: CO_2+CH_4



GWC of different household fuels in China: $CO_2+CH_4+CO+TNMHC+NO_x$



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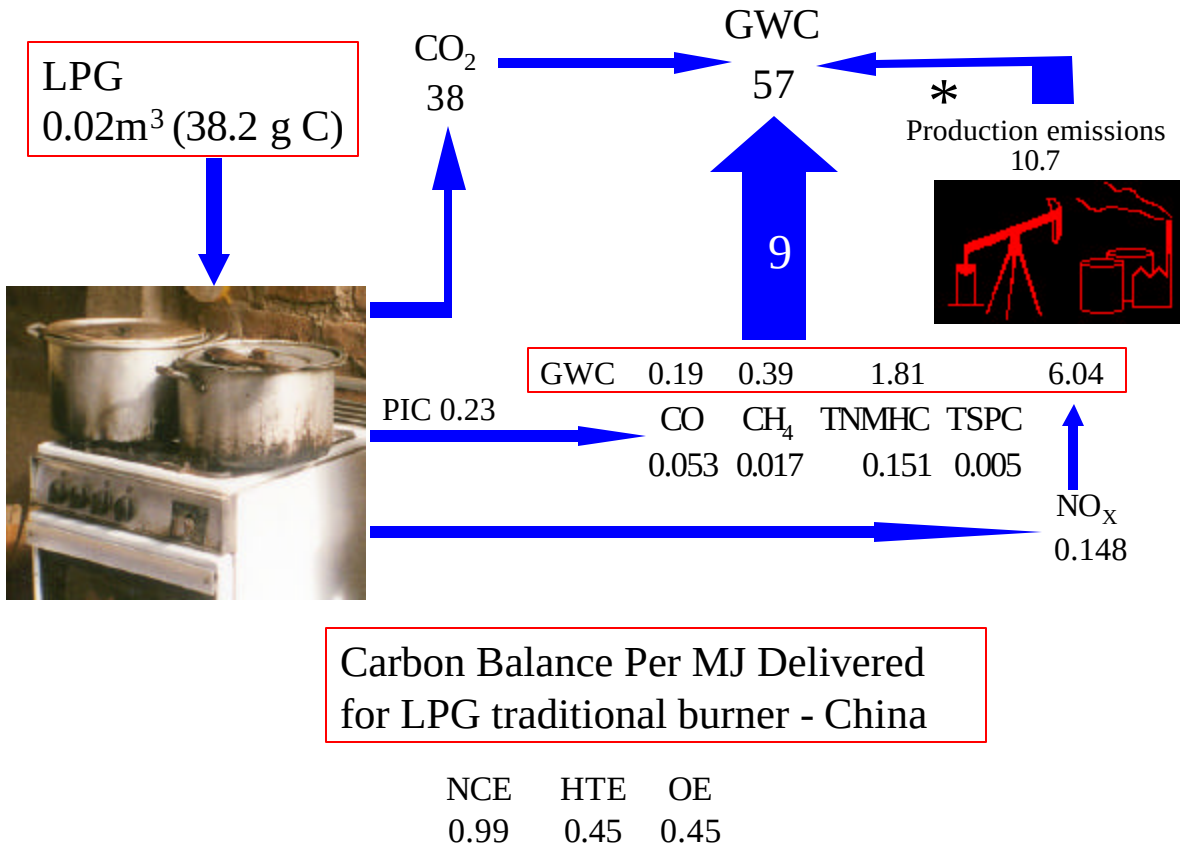
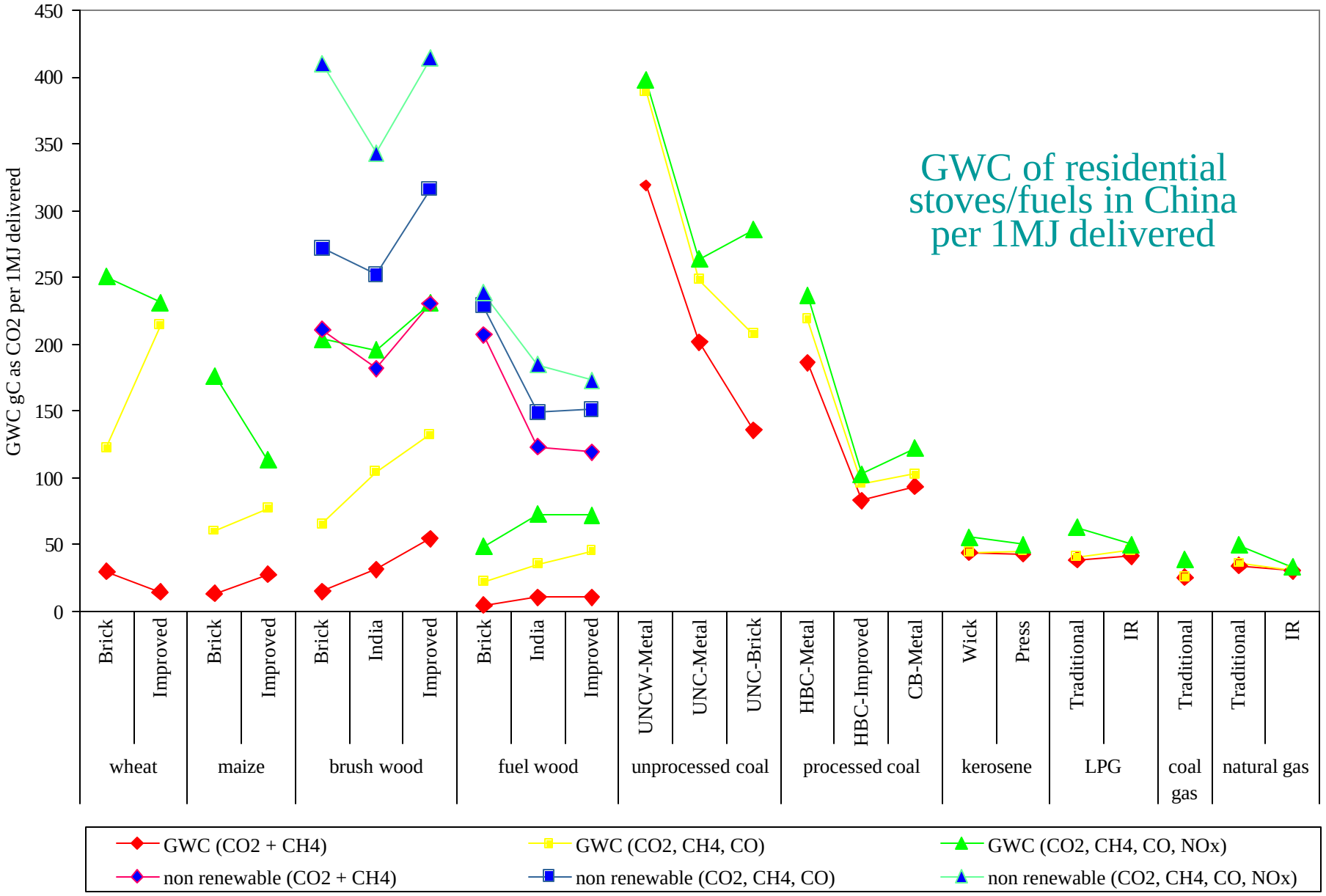
Tracing fuel carbon: LPG



*D. Pennise 2002



8 April 2002

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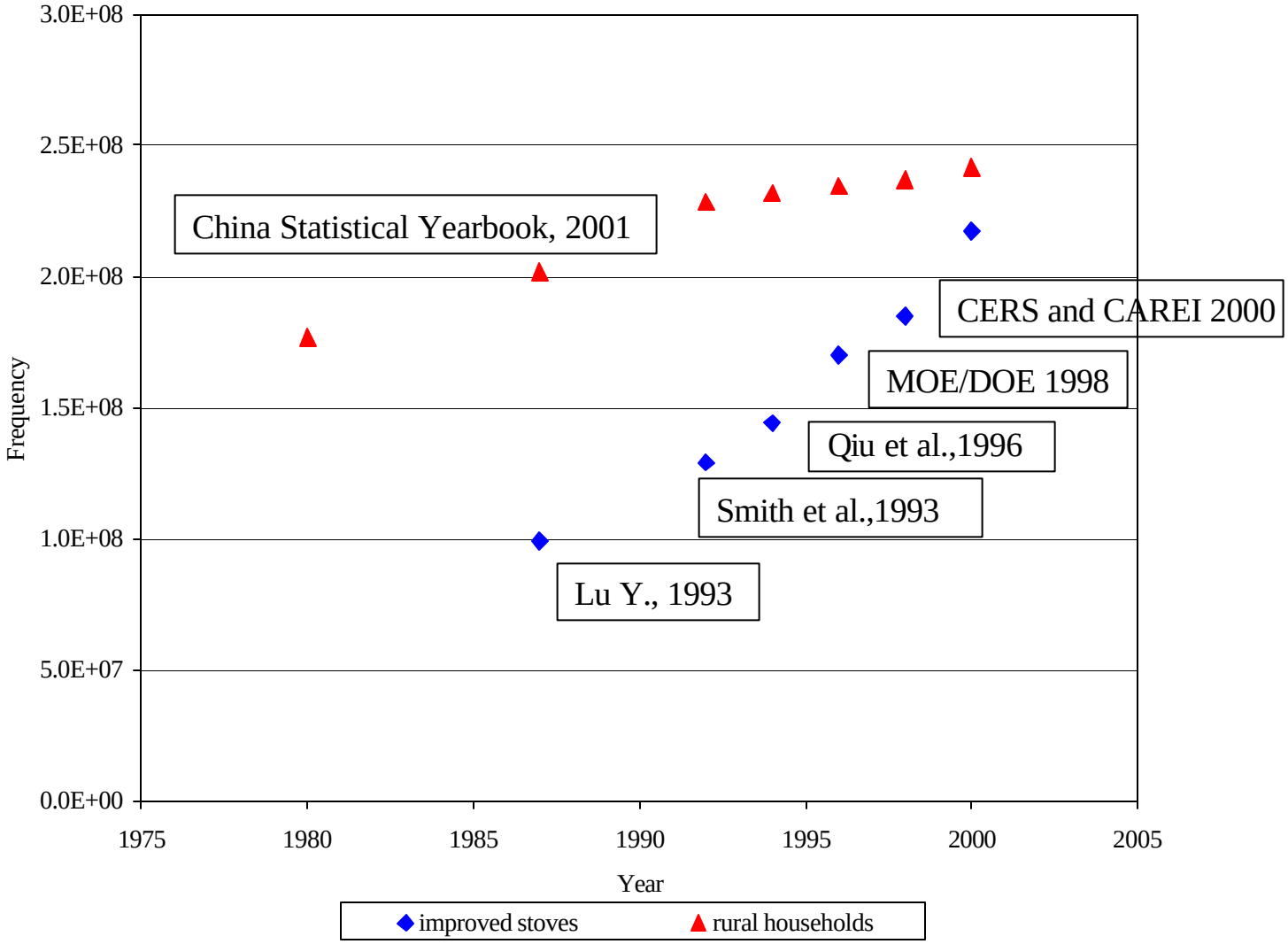
How can less fuel mean more pollution?

Stove	Overall Efficiency	Heat Transfer Efficiency	Nominal Combustion Efficiency
Traditional	14	15	97
“Improved”	27	30	90
Change = 73% more pollution per meal!	27/14 = 1.93x fewer kg fuel per meal		(1-0.90)/ (1/0.97) = 3.33x more PIC per kg fuel

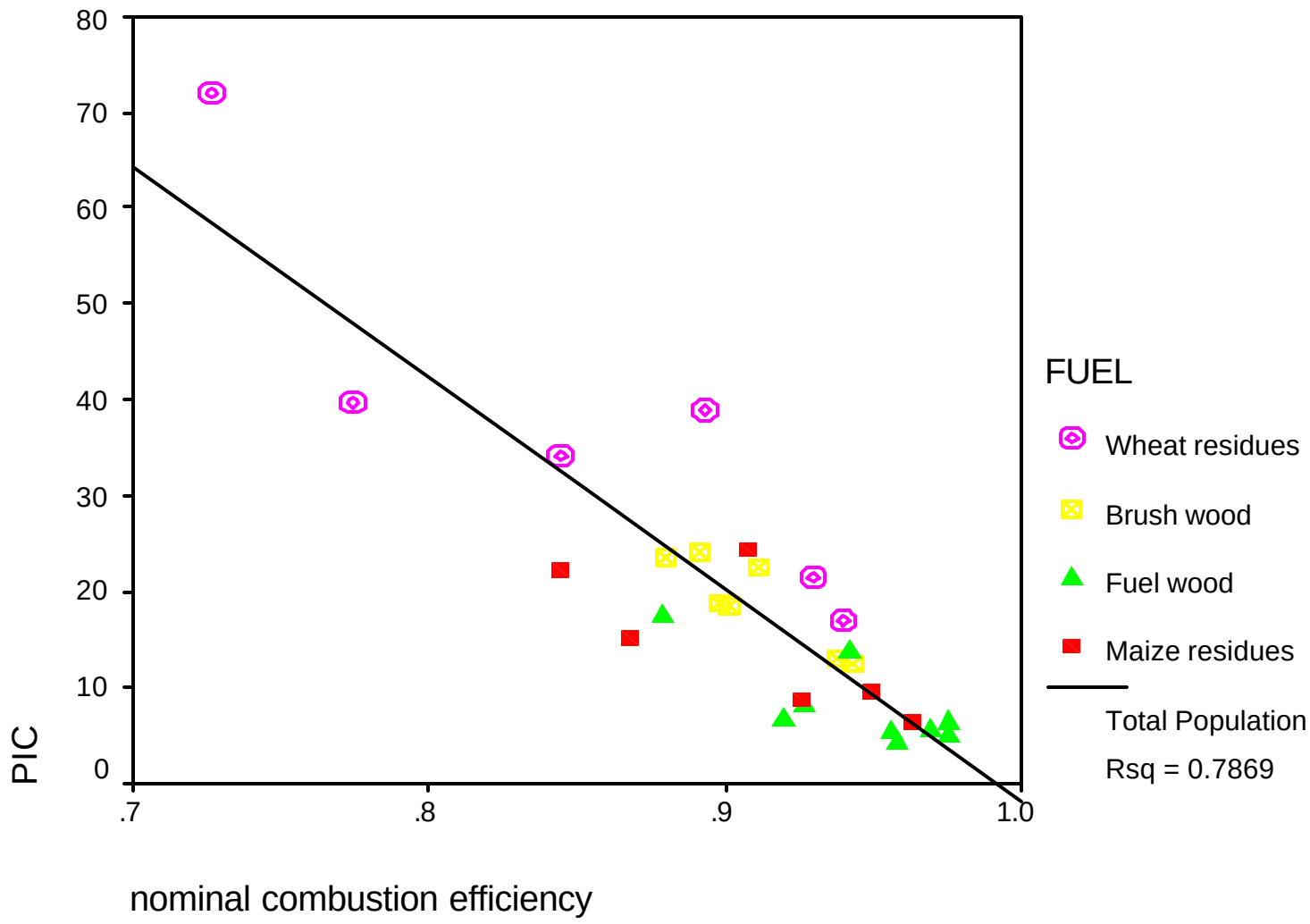
Dissemination of improved stoves in rural China and number of rural households



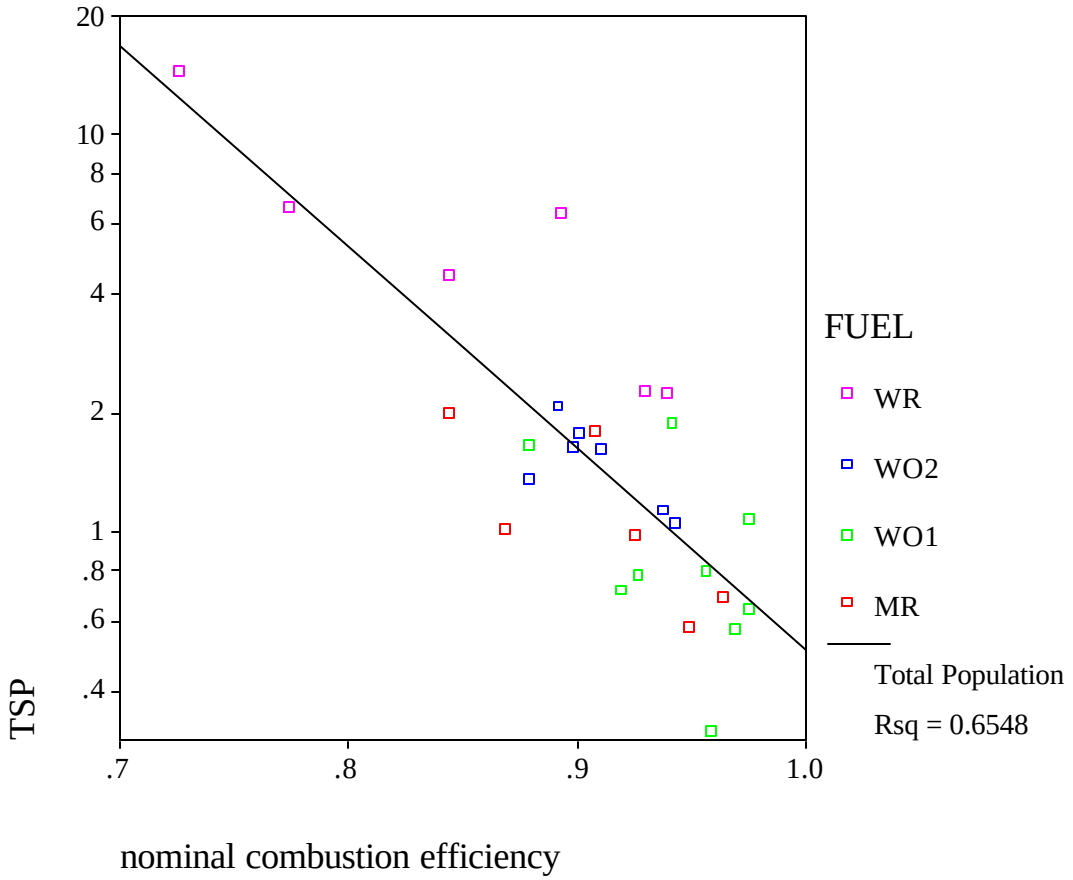
Chinese Improved Stove Program

- Probably the largest development project in history ~200 million households
- Major improvement in energy use
- Major reduction of human exposure to air pollution
- But
- Probably an increase in outdoor pollution and global warming

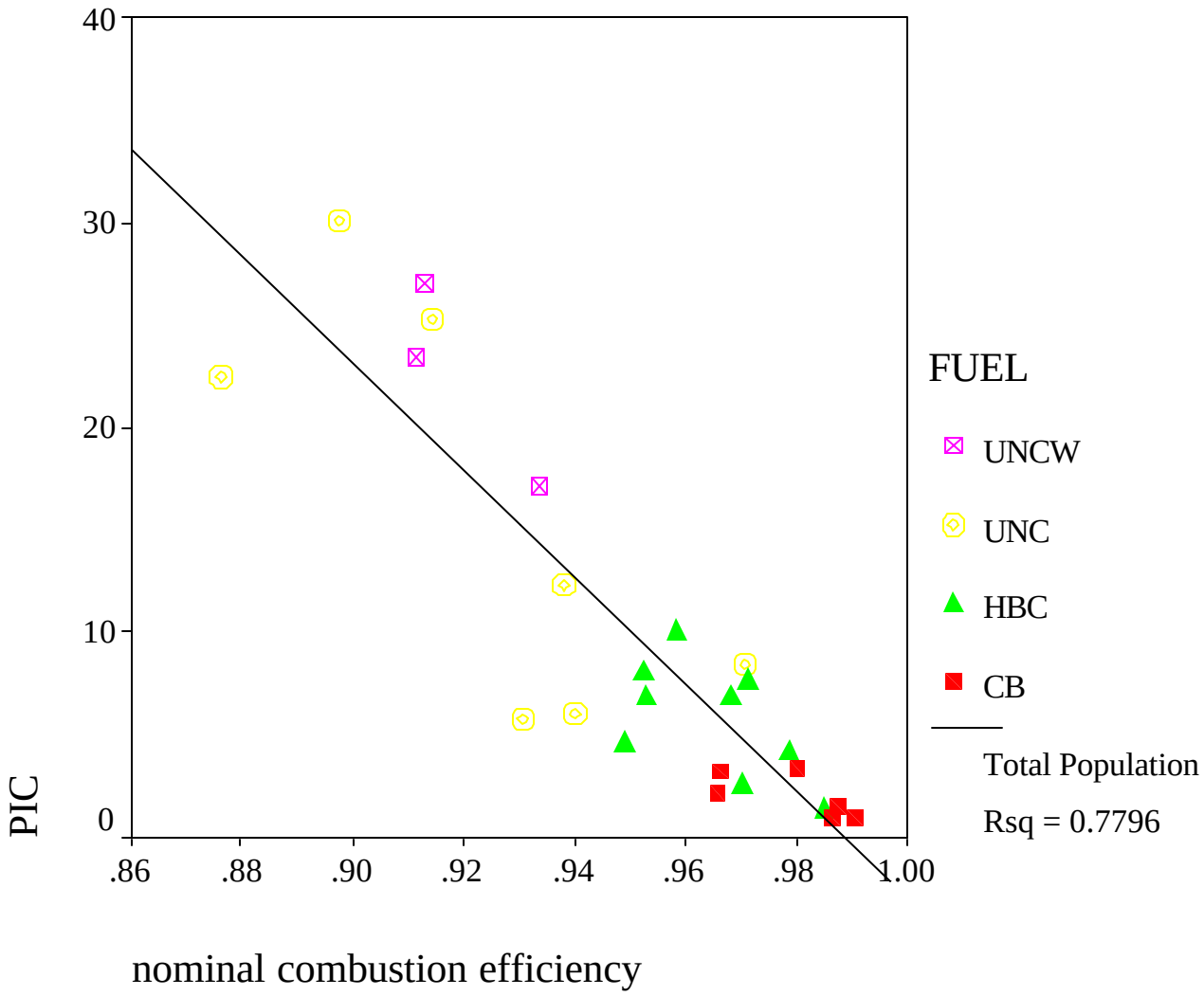
PIC vs NCE of biomass



TSP vs NCE for biomass



PIC vs NCE of coal



Model estimation of GWC

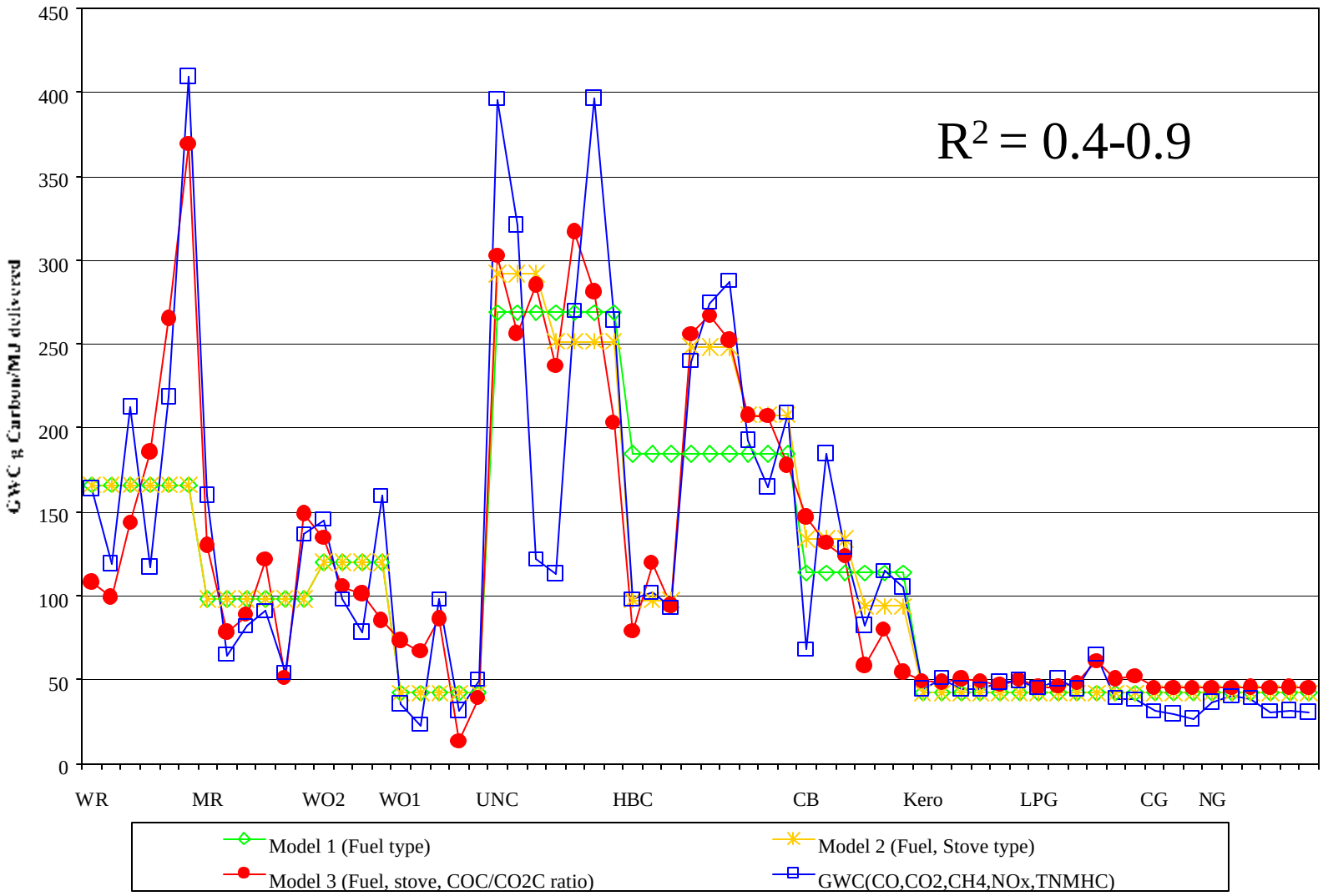
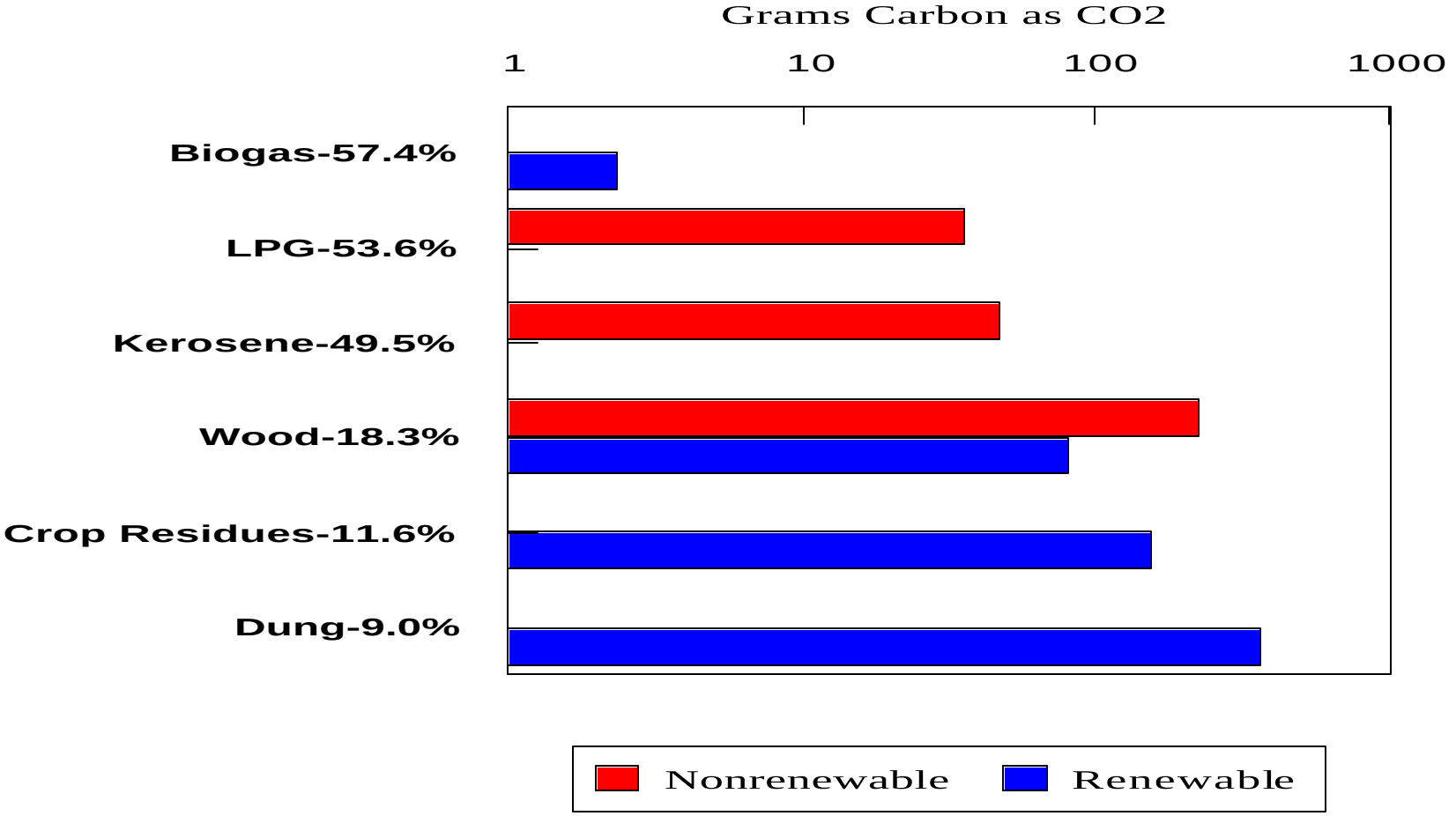


Figure 3.4. GWC per MJ Delivered

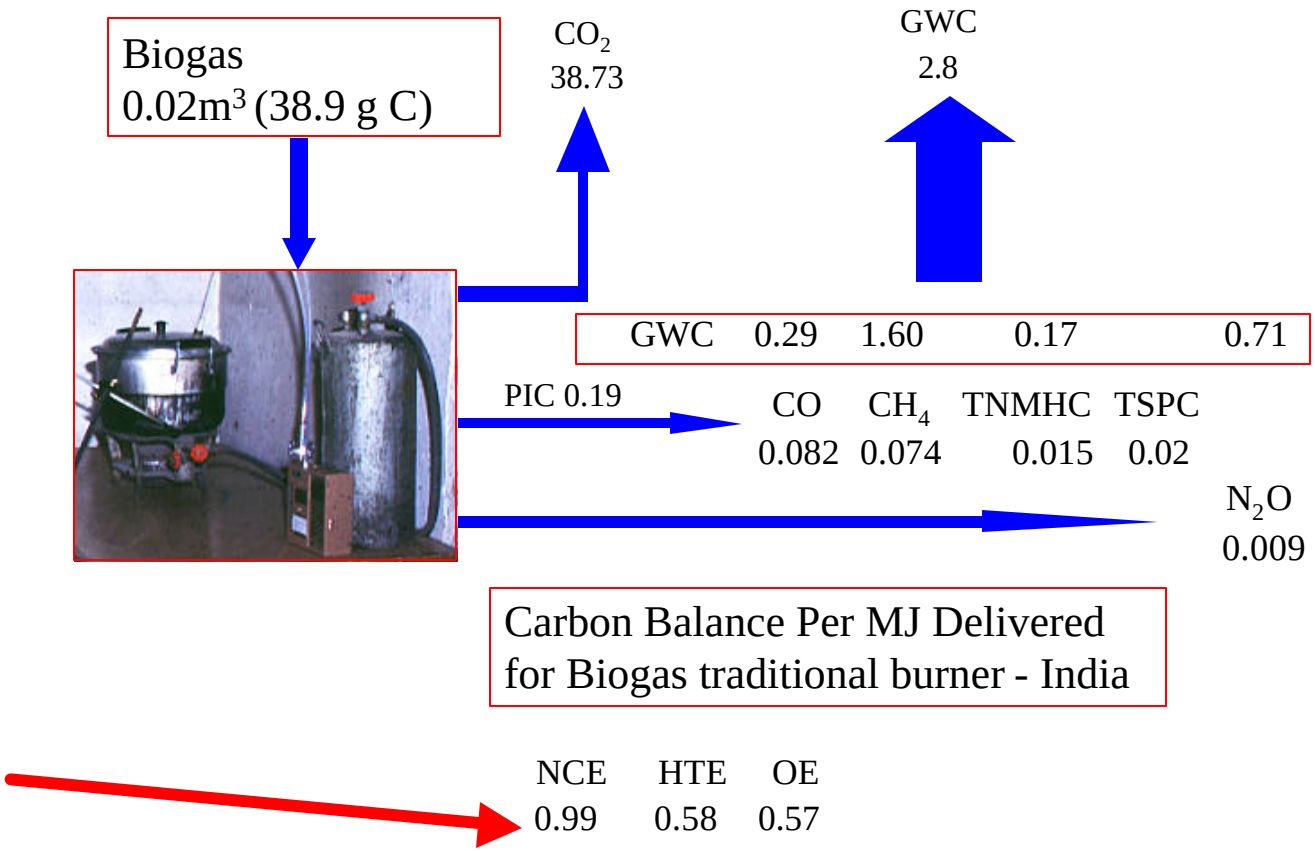
Weighted by Stove Distribution in India

Average Stove Energy Efficiency Shown by Fuel

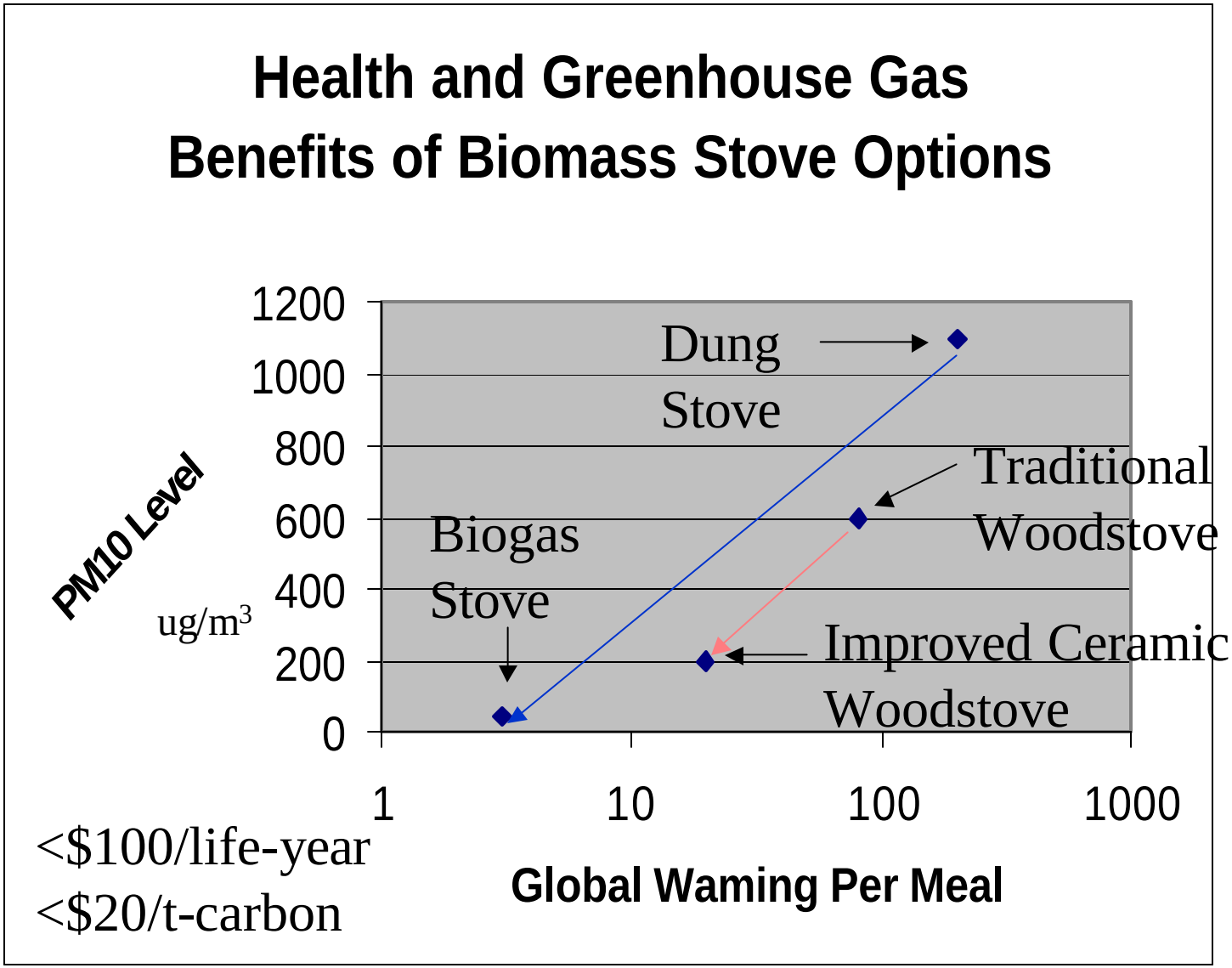


Warming from all GHGs emitted: CO2, CH4, CO, NMHC, N2O

Tracing fuel carbon: biogas



India


Health and Greenhouse Gas
Benefits of Biomass Stove Options
PM10 Level
ug/m3
1200
1000
800
600
400
200
0
Dung
Stove
Traditional
Woodstove
Biogas
Stove
Improved Ceramic
Woodstove
1
10
100
1000
<$100/life-year
<$20/t-carbon
Global Waming Per Meal
Grams C as CO2

Limitations

- these studies do not, of course, cover all fuel/stove combinations in use by the 2.4 billion people in China and India.
- many other variations: local cooking practices, variations in construction techniques, differences in fuel quality, wind speed, dampening patterns, and indoor/outdoor temperature differences.
- many cooking stoves are also heating stoves in the winter, and emissions factors per MJ delivered will be smaller if the stove is preheated. Current surveys try to assess this parameter

Global Importance of Biomass Fuel Cycles

Energy:

- Biomass makes up 10-15% of all direct human energy use
- Much larger proportion of carbon emissions from energy use
- It is 30-35% of energy use in developing countries
- It is 70-85% energy use in rural areas of developing countries
- It is probably still the most important fuel for the majority of humanity

Health:

- Cause of well more than half human exposure to respirable particulates
- Significant cause of ill-health worldwide

Global Warming:

- 2-5% of CH_4 emissions
- 6-15% of CO emissions
- 8-25% of hydrocarbon emissions
- 4-8% of all human-generated global warming from gases
- Significant contributor of BC

“Wood is the fuel that warms you twice” - true?

- Once when you chop it: 20 kJ
- Once when you burn it: 20 MJ

but also

- When it warms you through radiative forcing in the atmosphere: 20 GJ +
- Indeed, biomass is the fuel that can warm you four times: breaking, burning, forcing, and fever.